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Research Article

Contrasts in perception of the interaction between non-native species and climate change

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Abstract

Over the last century, intensification of human movement has resulted in a large-scale redistribution of species worldwide. In recent decades, this phenomenon has been further compounded by climate change, creating complex challenges in the management of non-native species. As effective management can be hampered by gaps in communication and understanding between scientific researchers, natural resource managers and the wider public, assessing consensus between these groups is crucial.

Here, we adopt an explorative approach to analyse three key groups concerned with the management of freshwater ecosystems – recreational fishers, natural resource managers and scientific researchers. Our objective is to better understand the level of consensus regarding the interaction between non-native species and climate change.

We found that, while scientific researchers and managers had varying opinions on the management of non-native species as driven by climate change, recreational fishers were almost unanimously opposed to the potential presence of non-native species, regardless of the nature of their introduction. Additionally, definitions of what constitutes a non-native species varied greatly between and within the groups.

Our results underline both the current lack of consensus on the definition and management of non-native species and gaps in understanding between and within the three groups regarding both the nature of non-native species and the range-shifting effects of climate change.

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Introduction

Over the last century, intensification of human movement worldwide has resulted in a large-scale redistribution of species, a trend that is predicted to continue at a similar pace in the coming decades (Seebens et al. 2020). Most of the redistribution of these non-native species has historically been driven by human translocation (Mack et al. 2000; Carpio et al. 2019). If these non-native species become established and begin to spread, their local impacts can include population declines and even local extirpations of native species and restructuring of food webs (Mack et al. 2000; Gallardo et al. 2016). Human activity has also resulted in climate change, which can reduce species' populations through warming temperatures and an increase in

the frequency of extreme weather events (IPCC 2021). In recent decades, climate change has compounded the effects of this redistribution of species. This can happen in a number of ways (Rolls et al. 2017). Firstly, through the direct movement – often termed 'range-shifting' – of species to higher latitudes and altitudes as a response to warming temperatures (Chen et al. 2011). Secondly, through allowing species to establish and spread upon introduction to ecosystems that were previously too cold for either process (Comte and Grenouillet 2013). Thirdly, through changing interactions between already-established non-native species and native species they had previously co-occurred with, such that native species are more negatively impacted (Gilman et al. 2010; Hein et al. 2014; Perrin et al. 2020a).

The complexity of the interaction between the non-native species and climate change leads to increasingly difficult management challenges. Successful management approaches, such as preventing the introduction of non-native species and conserving native species and communities, are dependent on three key groups – a) scientific researchers, who provide the research upon which management decisions are based (Pecl et al. 2017; Beaury et al. 2020), b) natural resource managers, who make and implement management decisions (Pietrzyk-Kaszyńska and Grodzińska-Jurczak 2015) and c) members of the public whose lives are affected by management decisions (henceforth referred to as 'the wider public'), whose approval is often necessary for the success of management decisions (García-Llorente et al. 2008; Gozlan et al. 2013; Verbrugge et al. 2013; Courchamp et al. 2017; Novoa et al. 2018; Deak et al. 2019; Kapitza et al. 2019; Kochalski et al. 2019).

Within research communities, there is substantial debate over both the terminology and management of non-native species, with traditionally popular terms such as 'invasive' and 'alien' viewed by some researchers as, at best subjective and, at worst pejorative (Shackelford et al. 2013; Head 2017; Abbate and Fischer 2019). The indirect role of climate change in range shifts in species means that range-shifting species are generally not termed as invasive or alien within the research community – though this is not always the case (Peterson and Robins 2003) – and there has been objection to the application of invasive frameworks to range-shifting species (Urban 2020). Here, we use the term 'non-native species' when referring to a term that is outside of its historically-defined native range.

Many natural resource managers (henceforth referred simply to as 'managers') have begun to incorporate the effects of climate change into management actions regarding non-native species (Rahel et al. 2008; Beaury et al. 2020), including habitat manipulation and restriction of dispersal in areas where native species are of conservation concern (Scheffers and Pecl 2019). However the strict maintenance of species assemblages in areas where the climate has rendered habitats unsuitable for native species may become resource-intensive and ultimately untenable (Scheffers and Pecl 2019). These difficulties are compounded by the fact that, amongst the wider public, climate change itself is enough of a controversial issue, with the phenomena sometimes rejected as a threat by members of the public, even those whose livelihoods are directly affected (van Baal et al. 2023). Knowledge of risks and management techniques amongst the wider public regarding non-native species also varies from region to region and over time (Bremner and Park 2007; Verbrugge et al. 2013; Ridbäck and Dietze-Schirdewahn 2017; Deak et al. 2019; IPBES 2023). Knowledge of a species' invasiveness and exposure to its negative impacts can increase negative perceptions of non-native species (Lindemann-Matthies 2016; Luna et al. 2019), yet these perceptions can often diminish over time as familiarity with them increases (Henke et al. 2024).

Gaps in communication or understanding between managers, scientific researchers and public stakeholders often hinder both the development and implementation of effective management policies (IPBES 2023; Gonzalez-Sargas et al. 2024; Kinsley et al. 2024), with potentially severe effects on the success of non-native species management. Examples of such disconnects with negative effects on management programmes are also plentiful (Temple 1990; Wynne 1992; Manchester and Bullock 2000; Bertolino and Genovesi 2003; García-Llorente et al. 2008; Gozlan et al. 2013; Arts et al. 2016; Niemiec et al. 2018; Anderson et al. 2019; Deak et al. 2019; Kochalski et al. 2019; Yletyinen et al. 2021; Kinsley et al. 2024). Discrepancies in views and understanding can be particularly harmful in situations where the wider public can be a significant vector for translocation of non-native species, such as the spreading of non-native fish species through freshwater rivers and lakes by recreational fishers. As such, an understanding of the wider public's perception of non-native species by both managers and scientific researchers is crucial (Nisbet and Scheufele 2009; Verbrugge et al. 2013; Shackleton et al. 2019).

We use semi-structured interviews with managers, researchers and the wider public (in this case recreational fishers) to assess perception of interactions between non-native species and climate change in an area where: a) climate change is progressing at an accelerated rate compared to the rest of the world (IPCC 2021), b) low endemic species richness means the impact of non-native species can carry particular ecological and cultural significance (Hesthagen and Sandlund 2007) and c) the wider public can be a significant vector for translocation of non-native species (García-Díaz et al. 2018; Carpio et al. 2019; Chapman et al. 2020). In exploring said perceptions we aim to identify pathways to integrate scientific, practical and lay knowledge and strengthen collaboration among the three groups. This allows for identification of appropriate management actions to handle these interacting effects of climate change and non-native species (Kapitza et al. 2019).

Methods

Personal interviews

Study system

In order to assess the contrast between perceptions of the interacting effects of climate change and non-native species among three groups – those who produce the scientific research (researchers), those who implement it (managers) and those who provide public approval of its implementation and experience its effects (recreational fishers) – we interviewed respondents from diverse locations throughout Norway in relation to freshwater ecosystems. Norway's location in the sub-Arctic and Arctic, immigration history and topography means that large parts of the country are relatively species-poor and subsequently vulnerable to the effects of non-native species (Hesthagen and Sandlund 2007). Translocations from well before the 1900s until the modern day by various institutions – including the church, the government and recreational fishers from inside and outside of Norway – have resulted in the spreading of native Norwegian species to areas they would not have previously been able to naturally disperse to, as well as the arrival of species non-native to all of Norway and, in some cases, to Europe (Hesthagen and Sandlund 2007; Sandlund and Hesthagen 2011). Many of these species like the pike (*Esox lucius*) or European perch (*Perca fluviatilis*) can have negative effects

on native ecosystems and species that are adapted to relatively cold temperatures, many of which are of cultural importance, such as the Arctic charr (*Salvelinus alpinus*) and brown trout (*Salmo trutta*) (Winfield et al. 2008; Borgstrøm et al. 2010; Sandlund et al. 2013; Hesthagen et al. 2015; Eloranta et al. 2019).

The increased rate of climate change experienced in the sub-Arctic and Arctic means that, in coming decades, many species that may not have been able to establish and spread through colder ecosystems may be able to do so (Rahel and Olden 2008; Hayden et al. 2017). Effective management of freshwater systems is therefore crucial.

Rotenone treatment of freshwater ecosystems is common throughout Norway to remove harmful non-native species and, while effective, it is expensive and ecologically damaging, so if rotenone treatment is applied, there needs to be assurance that non-native species cannot return easily (Perrin et al. 2020b). Additionally, there is an ongoing trend of dam removal throughout much of Europe, dams which could potentially currently act as dispersal barriers for non-native species (Sun et al. 2020). Norwegians in general consider themselves well-informed regarding threats to aquatic biodiversity relative to other countries and awareness of the danger presented by non-native species is higher than other similar European nations (Falk-Petersen 2014; Kochalski et al. 2019). Crucially, Norwegian fishers are aware of non-native fish species threats and, in some cases, even willing to aid in their removal (Guay et al. 2024). However, the country has seen a lack of agreement between management attitudes and scientific researchers and even within the research community, in regards to non-native species management in the past (Lundberg 2010). This makes consensus in the management of non-native and range-shifting species between researchers, managers and public stakeholders vital in the quest for effective management of Norwegian freshwater ecosystems.

Our study looks at contrasts in perceptions of the interactions between climate change and non-native species throughout Norway. As an explorative study necessitates an understanding of respondents' reasoning, we took a qualitative approach to data collection. There has been a bias towards quantitative methods in similar research in the past, which can limit understanding of the social context in which perceptions are founded (Kapitza et al. 2019). As such, we conducted personal interviews with members of our three chosen key groups; researchers, managers and recreational fishers (Table 1), in line with previous studies (Schüttler et al. 2011; Selge et al. 2011).

Respondent selection

A total of 30 interviews were conducted between August of 2019 and April of 2020. Interview respondents were chosen using the snowball method, as described by Miles and Huberman (1994). This requires an initial pool of contacts, who subsequently nominate other respondents that are suitable for the study. Our initial pool included contacts from a variety of organisations and regions, in order to avoid shared viewpoints potentially based on similar educational and career histories.

In compliance with requirements of the Norwegian National Research Ethics Committee, all respondents were given an overview of the topic beforehand, assured that their responses would be anonymous and informed of the intended use of their responses. Participation was voluntary and respondents could withdraw consent without specifying the reason for doing so. All interviews were anonymously recorded and subsequently transcribed verbatim. Any details which might have allowed the individuals to be identified, based on descriptions of their roles or locations, were removed.

Table 1. Description of respondents.

Interest group	Description	Number respondents
Researchers	Professionals associated with public or private research institutes not directly responsible for taking management decisions. Expertise in fish biology or ecology or freshwater ecology or hydrology.	8
Managers	Professionals associated with public organisations which are directly responsible for management decisions regarding freshwater bodies.	12
Recreational fishers	Individuals who participate in recreational fishing on a regular or semi-regular basis.	10

Interview structure

We used a semi-structured interview approach, in order to ensure that interviews flowed as naturally as possible with room for tangential discussions, while ensuring that several basic topics were covered (refer to Suppl. material 1 for interview guide). The first was their perception of a non-native species and whether or not several key factors played into their definition, including: a) method of introduction of the species, b) native habitat of the species and c) societal perception of the species. All three factors have been previously shown to influence perceptions of a non-native species, both among scientific researchers and the public (Warren 2007; Selge et al. 2011). While the English term 'alien species' can be considered as pejorative, it was used in the interview, as it corresponds more accurately to the widely-used Norwegian term 'fremmede art'. So as not to lead respondents into mentioning factors a-c, we asked them to define a non-native species, encouraging them to use examples when needed. We also wanted to gauge whether their view of non-native species changed over time and, if climate change had influenced the species arrival and/or subsequent impact. As recent research has suggested shifting management and research to focus on the impact of non-native species (Jeschke et al. 2014; Wallingford et al. 2020), we wanted to present respondents with a hypothetical situation in which a non-native species established itself and had a demonstrable and reasonably immediate impact, in this case the extirpation of a local species. This hypothetical situation was presented firstly as a result of climate-induced range expansion and, secondly, as a result of human translocation.[11] They were asked how they would react to both situations. For fishers, non-native species with which they were familiar were used as an example, in most cases the northern pike (*Esox lucius* Linnaeus, 1758) or European perch (*Perca fluviatilis* Linnaeus, 1758). They were asked how they would react to both situations.

Additionally, we asked the researchers and managers to name the primary concerns to their region, to capture whether or not non-native species and/or climate change were an acknowledged concern. We also enquired as to which species of fish researchers and managers considered to be of high conservation status. We asked recreational fishers questions relating to their fishing habits, including how long they had been fishing, which regions they had fished in, which species they preferred and whether their preferences changed on a seasonal or longer-term basis. This gave us insight into their perception of particular species.

No time limit was set on the interviews. Interviews lasted anywhere from 10 to 50 minutes, with most interviews taking about 22 minutes. Respondents were invited to talk freely and none expressed discomfort discussing the topic. Respondents occasionally had to be prompted to elaborate on answers in order to better

1 While every effort was made to assure respondents that the first scenario was hypothetical, two fishers rejected the premise outright, as they felt that introduction of novel species into their local environments was impossible in the absence of human translocation.

understand their reasoning. Although not always relevant, tangents were encouraged in order to allow respondents to better explain opinions or recount experiences. All respondents were offered the opportunity to be interviewed in Norwegian; however, 24 of the 30 were comfortable enough to complete the interview in English. Respondents were encouraged to switch to Norwegian any time they felt unable to adequately express themselves in English. Sixteen interviews were conducted in person, while the remaining 14 were conducted via web meeting. Whether or not the interview was conducted in person did not have a notable effect on the outcome and was, therefore, not used in further analysis.

Response analysis

Responses were categorised, based on two sections of analysis, one of which was common to all groups and one that differed for recreational fishers. The first section analysed which fish species recreational fishers preferred, so as to ascertain whether potential future extirpations would affect the species for which they preferred to fish. We also determined whether or not these preferences had changed over time. For researchers and managers, the first section sought to analyse which species were of high conservation status to their region and for what reasons. We also determined whether or not non-native species and/or climate change were of primary concern and which other factors were considered as primary concerns.

The second section concerned non-native species. We first determined, based on given definitions, whether subjects considered: a) method of introduction, b) societal perception and c) whether the species was native to the part of the country as an important facet of the definition of a non-native species. We then determined whether subjects reacted negatively to the possibility of species extirpations in their local freshwater ecosystems driven by a range-shifting species and whether this response varied when turnover was driven by a non-native species that had been directly translocated by humans. We also determined (although this was not directly elucidated by several respondents) whether or not they thought management action was appropriate in such situations.

In presenting our results, we begin by summarising general findings, then elucidate these findings using quotes from selected respondents. Respondents are referred to by an acronym referring to their respective interest group and order in which they were interviewed. As such, our seventh respondent, a recreational fisher, would be referred to as F-07.[22]

Results

The following section will present results, starting with the preferences of recreational fishers, followed by species of conservation concern and local anthropogenic stressors according to managers and researchers. Perceptions of non-native species are then described, followed by reactions to the two hypothetical scenarios.

For the sake of brevity, henceforth the extirpation of local species as driven by range-shifting species will be referred to as climate change-driven turnover.

2 Respondent F-04 was in fact three individuals who chose to be interviewed at the same time. As they almost exclusively fished together as a group and responses generally corresponded with one another, their responses were collated into one.

Extirpation of local species driven by non-native species which arrived as a product of direct human translocation will be referred to as translocation-driven turnover.

Extended responses from all respondents are openly available in Perrin et al. (2020c) (https://doi.org/10.5281/zenodo.3991516).

Fishing tendencies

Nearly all fishers interviewed expressed a preference for salmonids, namely brown trout and arctic charr. Several respondents mentioned the value of their preferred species as food fish.

> ***F-18:*** *I went consistently for brown trout since I was a kid, because that's the most common fish in our region. Here, the population of brown trout is dominant in rivers and lakes. It's the most exciting fish to do sportfishing for.*

With a few exceptions, these tendencies did not change on any short or long-term basis. Most respondents had fished for their preferred species since they were children. There was some preference for ice-fishing in the winter which restricted fishers to catching charr.

Three respondents also mentioned a dislike of pike and/or perch as a food fish and five specifically stated that they would no longer fish at lakes or rivers where these species had become established.

> ***F-07:*** *I've never fished for pike. But I know lots of people who fish for pike. It's not a good eating fish, like trout is.*

Species of high conservation status

Among managers, arctic charr, brown trout and salmon were each mentioned seven times as species of concern. Grayling, eel, pearl mussel, european bullhead, asp, fourhorn sculpin, white bream and vendace were also mentioned. Several admitted that, while they would like to see more focus on the latter species, salmonids were prioritised primarily for economic reasons, although, in some regions, salmonid species were also declining.

> ***M-24:*** *From a biological point of view I guess all species have the same value, from a financial point of view I guess trout and char are the biggest resource...*

All eight researchers mentioned at least one salmonid as a species of concern. Burbot, pearl mussels, lampreys, sculpins, cyprinids and notostracan crustaceans were also mentioned.

Local anthropogenic stressors

Non-native species were mentioned as a primary concern to their freshwater ecosystem by five of the eight researchers, with climate change mentioned as a primary concern for six. Eight of the twelve managers mentioned non-native species as a primary concern and eight mentioned climate change.

Perception of alien species

Three of ten fishers mentioned method of introduction in their definition of a non-native species. Respondent F-14 claimed that species that dispersed naturally were non-native, with respondent F-29 feeling that species dispersing naturally were "not necessarily alien" and respondent F-11 claiming that a non-native species "had to be introduced by humans". No fishers mentioned social perception of species in their definition. Two fishers mentioned the species native range, with respondent F-26 defining non-native species as those that are "not native in Norway" and F-05 defining species from the east of Norway as 'unnatural'. All definitions referred generally to fish not belonging in the region or specific lake.

> ***F-18:*** *It means species who aren't originally from that environment. So species you wouldn't have found there originally.*
>
> ***F-27:*** *The definition for me became quite narrow because one of my favourite waters became infected by pike, by some people placing it there because they think it's fun to fish for it. So for me that would be an alien species in that water, it's not supposed to be there.*

Seven of the twelve managers mentioned method of introduction in their definition of a non-native species. Of these seven, two definitively named species that spread naturally as non-native species.

> ***M-02:*** *Alien species are primarily those set out by humans. I maybe don't have a clear definition, but if they come here by themselves they can also be alien species.*

Two managers stated that non-native species needed direct human help to move.

> ***M-21:*** *I think of course you have had a natural extension and retraction of species always throughout the history of the earth. And of course climate change is affecting this in an unnatural way, but still it's not the same as human transportations of species.*

The other three managers did not have a definitive stance either way, but gave impressions on the subject.

> ***M-09:*** *I'm mainly thinking about those who are not spreading by themselves but who are spread by humans. But also those who are coming because of human induced climate change. I think that's not so easy to point out if it's totally alien species or just slightly expanding because of a natural variation.*

Three managers mentioned social perception when defining non-native species. Respondent M-20 defined non-native species as something "we don't like", whereas respondents M-24 and M-10 admitted that social perception could influence management approaches to non-native species, though they still classed species as non-native regardless of social perception.

Seven of the twelve managers mentioned whether or not the species was native to Norway as an aspect of the definition. All stated that species which were native to Norway, but not to a local region, should also be classified as non-native in that region.

Six of eight researchers mentioned the method of introduction as an aspect of the definition of a non-native species. Of those, four stated that species that moved on their own into new regions were non-native.

> ***SR-17:*** *I think it's a species that's coming to an area where it hasn't been for decades. So it varies, it can come naturally, moving slowly through freshwater species, like some of the alien species we have here that are coming from Sweden.*

The other two stated that non-native species needed direct human help to move. Only one researcher mentioned social perception in their definition, with respondent SR-25 claiming the definition was "value-based". Two researchers included whether or not the species was native to Norway in their definition, with both stating that species native to a certain region of Norway could still be classified as non-native in other areas.

> ***SR-19:*** *I know when we use this term we need to specify if we mean truly alien, like not even belonging in this country, or just having moved to a new area. But for me they mean both...*

Perception of climate change-driven versus translocation-driven turnover

All fishers felt negatively about climate change-driven turnover, with all citing their inability to fish for their preferred species as the main reason. Several used strong or emotive language in their reaction to the hypothetical scenario.

> ***F-18:*** *F*** off. Would be my answer. It would be a terrible situation for my passion. It's that easy. I don't have a big interest in dry fly fishing for perch or pike.*

Only one respondent mentioned ramifications for the local ecosystem as a contributing factor to his reaction. Several respondents recognised that climate change can make lakes more suitable for other species, but that these lakes should still be preserved.

> ***F-27:*** *That would feel bad, it would ruin my waters. I wouldn't like that, and I think we should try to prevent it, even though it's climate change, we should stop those things from happening.*

There was no inversion of response when asked how they felt about translocation-driven turnover; however, four felt even more negatively about this possibility.

> ***F-14:*** *I think I would get more angry if it was humans. But I wouldn't be happy either if it was climate change. People should know... the consequences of moving species over.*

While some fishers did feel negatively about the prospect of climate change-driven turnover, they felt it was unlikely to occur in their local ecosystems in the near future.

Nine of twelve managers felt negatively about climate change-driven turnover. Three of those managers cited potential effects on local fishers as a contributing

factor to their reactions. Of the nine, only four felt that management steps should be taken to prevent non-native species from establishing in lakes as a result of range-shifts.

> ***M-22:*** *...some species will spread, even though they're alien species, because you simply don't have the possibility to stop them. But in other respects, I would resent or try to stop such a development... Because you also have to bear in mind that these are alien species and you should give the native species a possibility to adapt from climate change...*

Of the managers who did not feel that management actions were warranted in the case of climate change-driven turnover, most stated that they felt it was futile to combat long-term changes.

> ***M-21:*** ***...****it's a result of a new climate situation, and it's not possible to try to fight this I think. I think the species living in the environment has just adapted, and we lose some and we get some… It's not possible to try to maintain the status quo if the climate changes.*

The manager who did not feel negatively about climate change-driven turnover, respondent M-01, also did not feel negatively about translocation-driven turnover, stating that, as their region of concern did not have any incoming non-native species of concern, no action would be needed.

Five of the nine managers who felt negatively about climate change-driven turnover stated that they would feel more negatively about translocation-driven turnover.

> ***M-24:*** *I think then I could direct, my anger, my mood I guess, my emotions would be directed. More disappointment and anger, those kinds of feelings I guess. We would have to look at how this was allowed to happen, and adapt a management scheme to it I guess.*

Of the five managers who felt negatively yet did not feel that management steps should be taken to mediate climate change-driven turnover, four felt that management steps would be warranted in cases of translocation-driven turnover, with one explicitly stating that they had performed management actions in such cases.

> ***M-21:*** *If a species is moved by humans into a new area we will actively try to remove it again. We have a lot of examples of that, we've spent money on that. It's very difficult to succeed with such an approach, but we do it.*

Four of the eight researchers did not feel negatively about the possibility of climate change-driven turnover, with many arguing it was a natural process.

> ***SR-25:*** *If for some reason a new species is able to survive in an area now that it couldn't before, I think that's life. And to put a lot of management efforts into avoiding that, I think that's a bad solution. There are so many other things to use limited resources on.*

Four researchers felt negatively about the process, but two did not think that management was warranted as it would be futile.

> ***SR-19:*** *I would also feel that it was nothing we could do, and accept it, and try to focus on something else... because it would be very difficult to artificially keep other species alive in systems which isn't suitable for them any more.*

All researchers had a negative opinion concerning the prospect of translocation-driven turnover. Of the six who did not think that management action should be taken to avoid climate change-driven turnover, all six expressed that it was appropriate to combat translocation-driven turnover.

> ***SR-16:*** ***...****obviously if there is a human introduction, then I would view that more negatively … with human induced temperature increase, that would be a pretty strong concern, but then with a direct introduction, that would be even more of a concern, because we have the knowledge, to know that we shouldn't really do that, that that will mess up the natural ecosystems.*

Discussion

Ensuring that there is correlation between the views of scientific researchers, managers and the general public is critical when implementing conservation strategies. This is especially the case when the strategies involve complex and controversial subjects, such as the interacting effects of non-native species and climate change (Pecl et al. 2017). Here, we aimed to identify possible causes of disconnect between these different groups in their perceptions of the interacting nature of climate change and non-native species and their subsequent impact on freshwater ecosystems. Our analysis shows that attitudes vary within and between managers and researchers to the impacts of non-native species when they are, in part, driven by climate change. However, the same impacts are almost unanimously negatively viewed by a public group – in this case recreational fishers – with the impact of climate change on the introduction of the non-native species having very little effect on their opinions.

The most prominent contrast between the groups was the fishers' response to climate change-driven turnover compared to that of the managers and researchers. While there were conflicting feelings about climate change-driven turnover among the managers and researchers, the prospect was unanimously rejected by recreational fishers. Although some admitted they would be angrier if human translocation were the sole culprit, many stated that they would view the presence of a non-native species and/or the loss of native species negatively, regardless of whether or not climate change had influenced the outcome. Many felt that management action should be taken to prevent such turnover wherever possible. This lack of consensus between groups is not unexpected, as instances in which there are disagreements between local stakeholders who are directly impacted and managers and researchers are far from uncommon (Redpath et al. 2013; Manjarrez-Bringas et al. 2018).

Contrast in the impacts and management of non-native species and climate change was present within groups as well, most notably among managers and scientific researchers. While most expressed negative opinions about the process, there was a variety of opinions in both groups regarding whether or not management action should be taken. While some supported removal, many found it to be futile – even in cases where lack of removal would result in a local extirpation –

while others thought it would be unwarranted even if removal were possible. This is unsurprising, as dialogue regarding the concept of range-shifting species is often polarised (Shackelford et al. 2013). However, it does suggest a lack of consensus on a management issue that may become more pressing in the coming decades.

The unanimous rejection of new species by fishers was often mentioned in conjunction with the new species having little or no perceived value as a food resource. Further investigation into how heavily the value of a species as a food resource factors into public perception of a species is warranted, including whether perception would shift if the incoming species had more in common with preferred species, such as the previously introduced species brook or lake trout. Familiarity with a species has previously been shown to affect public perception of them as non-native or not (Kochalski et al. 2019) and emotion can often play a larger role than rationale in shaping opinions on fish as a food resource (Verbeke et al. 2007). While pike does not appear to be a preferred food-fish in Norway, it is well-regarded elsewhere in Europe (Linhart et al. 2002). Qualitative studies in areas where species have been established for longer periods of time may shed more light on the role of the public's familiarity with non-native species in their reaction to them.

Similar contrasts in the perception of climate change-driven turnover are evident in the varying definitions of non-native species across the different groups. While it featured in the definitions of over half both the managers and researchers, method of introduction was generally not addressed by the fishers in their definition of non-native species. Furthermore, although several fishers acknowledged that climate change would likely alter nearby ecosystems, only one alluded to the possibility of new species arriving. This could be a result of a lack of knowledge regarding the effects of range shifts as a product of climate change or an association of non-native species as primarily being a product of human translocation.

Given the global restructuring of ecosystems that is currently taking place as a product of climate change gradually altering species ranges, more open communication among all three groups should be a priority in ecosystem management. Going forward, perhaps the most notable area of disconnect between the groups is the question of whether management actions should be taken to prevent the impacts of non-native species, even when such impacts are driven by climate change. The reluctance to commit resources to stop such impacts among managers and researchers compared to the insistence that such management was required by the fishers represents the most obvious source of potential future conflict identified in this study. Previous research in marine systems has suggested that fishers do not tend to automatically link climate change to the arrival of new species (van Putten et al. 2016) and that educating public stakeholders is crucial to the success of future policy regarding climate change and range-shifts (Nursey-Bray et al. 2012; Pecl et al. 2017).

More open communication among the three groups, particularly between scientific researchers and public stakeholders, will be key to increasing support for management actions in the future (Courchamp et al. 2017). To ensure uptake and support for management actions, the scientific research that drives them needs to be trusted by recreational anglers (Wynne 1992; Weyl et al. 2014). Both national and more local managers have a key role to play in building this trust, as they can often sit as the intermediary between the two groups. Local managers possess valuable local knowledge applicable to different regions, which can ensure better knowledge transfer (Nisbet and Scheufele 2009), presumably resulting in

increased public understanding of invasive species' effects and more support for their management (Lindemann-Matthies 2016). Managers, particularly those in national bodies, can also facilitate the formation of collaborative networks across regions, ensuring both more cooperative interaction between affected regions and more standardised messaging, both of which can increase the efficacy of management policy (Courchamp et al. 2017; Niemiec et al. 2018; Kinsley et al. 2024).

The facilitation of regular workshops involving all three groups would enable direct dissemination of scientific research to anglers, but also allow researchers to better understand both management challenges and the public's perception of their research (Shackleton et al. 2019). Such workshops would also provide an opportunity to include recreational anglers in management projects from the outset, a tactic which often results in higher public uptake of management initiatives (García-Llorente et al. 2008; Weyl et al. 2014; Pecl et al. 2017; Novoa et al. 2018). A bonus would be training in scientific communication among scientific researchers, as effective communication requires framing scientific research for specific target audiences (Nisbet and Scheufele 2009). Repeated interactions between researchers, managers and the public also have the potential to build trust and increase the acceptance of management decisions.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

In compliance with requirements of the Norwegian National Research Ethics Committee, all respondents were given an overview of the topic beforehand, assured that their responses would be anonymous and informed of the intended use of their responses. Participation was voluntary and respondents could withdraw consent without specifying the reason for doing so. All interviews were anonymously recorded and subsequently transcribed verbatim. Any details which might have allowed the individuals to be identified, based on descriptions of their roles or locations, were removed from the transcriptions.

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Author contributions

SP and CL conceived the idea. SWP, CPW and CL designed the methodology. SP and AGF sourced the initial pool of respondents. SP collected and analysed the data. All authors contributed critically to the drafts and gave final approval for publication.

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Data availability

Extended responses from all respondents are openly available at https://doi.org/10.5281/zenodo.3991516.

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Supplementary material 1

Interview guide

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Data type: pdf

Explanation note: A guide used for semi-structured interviews to assess perception of interactions between non-native species and climate change in Norwegian freshwater ecosystems.

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